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ABSTRACT

The associations among cognitive automatization, abstract problem solving, and educational performance were studied using 127 fourth to ninth grade students. A number of measures of fast, automatic, and fluent performance (FAF measures) were used: writing the alphabet; reading from a word list; and mentally performing arithmetic operations. The Survey of Cognitive Skills, a process-oriented inventory, was used to assess problem solving skills and educational outcomes. Learning strengths and weaknesses were evaluated while the subjects performed academic tasks: paper and pencil mathematics problems; creative paragraph writing; and reading comprehension. Hierarchical regression analyses were applied to determine the contributions toward academic performance of the fast, automatic, and fluent automatization tasks and the problem solving measures. Multiple regression analyses were also performed. Results indicated that prediction of the educational outcomes differed with respect to the relative contributions of the FAF automatization measures to the problem solving tasks. More outcome variance was explained for reading comprehension and mathematics than for written language. The outcome-specific FAF measure was much more dominant for mathematics than for reading comprehension or writing. Mathematics and writing performance became proficient when the basic mathematics and writing skills and processes were automatic. (GDC)

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AUTOMATIZATION AND ABSTRACT PROBLEM-SOLVING AS PREDICTORS OF ACADEMIC ACHIEVEMENT

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ABSTRACT

This study investigated the associations among automatization, problem-solving, and educational performance in 9-14 year olds. Three tasks were developed to measure fast, automatic, fluent performance in the basic academic skills, namely, reading, written language, and mathematics. Hierarchical regression analyses indicated that prediction of the educational outcomes differed with respect to the relative contributions of the skill-specific and generalized automatization measures as well as the problem-solving tasks. These findings suggest the importance of developing second-level automatization measures to be used with problem-solving and cognitive tasks in the diagnosis and treatment of certain learning problems.

AUTOMATIZATION AND ABSTRACT PROBLEM-

SOLVING AS PREDICTORS OF ACADEMIC ACHIEVEMENT

Subject Index Terms: Education/Learning

Recently, there has been a burgeoning of empirical and theoretical research which has applied various information-processing paradigms to intelligence, cognition and learning (Glaser, 1984; Pellegrino & Glaser, 1982; Sternberg & Wagner, 1982). Pellegrino and Glaser (1982) have identified three interrelated components of performance which differentiate high from low aptitude. These components include speed of performance, conceptual knowledge of content, and knowledge of the procedures required to approach tasks. They conclude that individuals with high aptitudes in cognitive and learning areas display strengths in reasoning skills because they combine content knowledge with the procedures and processes needed to solve particular problems. In general, the interrelation among these three facets of aptitude have not been widely studied. The present study was designed, therefore, to investigate one aspect of this association by evaluating the combined influences on educational achievement of fluent automatized skills and abstract problem-solving.

Speed of performance and automatic processing have been studied extensively in relation to working memory in children with learning disorders (e.g., Denckla & Rudel, 1974; Wolf, 1983). In particular, rapid automatized naming has been the focus of investigation in children with learning disorders (e.g., Hasher & Zacks, 1979; Lorsbach, 1982; Posner & Snyder, 1975). Studies have generally focused on speed and accuracy of word finding and naming in relation to single stimuli such as pictures and alphabetic letters. A broader model of automatized learning has been provided by Sternberg (1980; Sternberg & Wagner, 1982). He has suggested that individuals with learning disorders exhibit weaknesses in the acquisition, retention and transfer of information which may derive from inadequate automatization of various components of information processing.

Definitions of the concept of automatization vary. However, most refer to an overlearning process such that minimal attention is necessary for performance (Broverman and Broverman, 1964). Most automatization research has used reading as the outcome measure, largely a result of the definitive theoretical work of Laberge and Samuels (1974). Their model has described the link between skilled reading performance and automatic activation of word meanings in semantic memory. It is proposed here that the concept of automatization needs to be more extensively investigated in relation to a broader range of educational processes. It is also suggested that the method of measuring automaticity be expanded to include rote academic tasks. This broadening of the concept of automatization is particularly important in light of the recent studies of rehearsal strategies and memorization in poor readers (e.g. Bauserman and Obrzut, 1981).

It is therefore proposed that second-level automatization processes may exist whereby various skills acquired in the first few grades must be transferred and coded in rote memory so as to become automatic before more advanced learning can occur. These automatized skills should enable the child to direct attentional and information processing resources towards the more complicated abstract organizational demands of reading, written language and mathematics. It is hoped that delineations of these interactions in normal achievers will facilitate further investigations of learning disorders.

The present study was designed to investigate a number of the issues discussed above. The specific objectives were:

1. To develop a set of measures for assessing certain second-level automatization processes necessary for fluent and efficient educational performance. These are referred to here as "FAF" tasks as they assess fast, automatic, and fluent performance in those basic academic skills which are mastered in the early grades (reading, written expression, mathematics).

2. To determine the additive contributions of automatization and problem-solving towards performance on measures of reading comprehension, written language, and mathematics.

3. To contrast the structural patterns characterizing these three educational skills namely, reading comprehension, mathematics, and written language, by comparing the associations among automatization processes and problem-solving strategies.

4. To begin to assess the extent to which measures of fast, automatic and fluent performance (FAF measures) are skill-specific or evaluate general learning and automatization.

Subjects

The sample consisted of 127 students with a mean age of 12.1 years and an age-range of 9-14 years. Subjects were selected randomly from grades 4 to 9 in several Massachusetts and New Hampshire public schools. Most of the students were from middle-income families.

Materials

FAF Performance Measures

A set of measures was developed to evaluate the rote skills necessary for efficient performance in reading, written language, and mathematics.

(a) The FAF writing measure was a timed alphabet task. Students were instructed to write the cursive, lower-case alphabet as quickly as possible.

(b) The FAF reading measure consisted of 48 words. Most were selected from the Dolch Sight Word List (Dolch, 1978) and were at or below the second grade readability level. Several compound words were included whose syllabic components were also at or below the second grade readability level. Students were required to read as many words as possible in 20 seconds.

(c) The FAF mathematics measure assessed the child's ability to apply basic math operations rapidly and fluently. This consisted of a set of simple mathematics facts which incorporated the four basic operations (+,-,÷,X). These examples were presented orally by the

examiner. Students were required to solve the problems mentally as quickly as possible. A time-limit of 45 seconds was imposed.

(2) Problem-Solving Tasks

Problem-solving was assessed using two subtests from the Survey of Cognitive Skills (The Children's Hospital). This is a process-oriented inventory designed to evaluate reasoning ability and higher order cognition.

(a) The Series Completion task consisted of sequences of geometric figures with the last figure omitted from the series. Subjects were required to identify the missing figure from a multiple choice array and to explain their judgements. This task measured pattern analysis skills, working memory, and the ability to detect and apply general themes.

(b) The Category Shift Task assessed flexibility in shifting from one problem-solving approach to another. Subjects sorted four pictures in two different ways and explained their response. This task focused on organization and categorization skills, cognitive flexibility and the ability to reflect on and to recognize the problem-solving strategy used.

(3) Educational Outcome Measures

Three subtests were selected from the Survey of Educational Skills (The Children's Hospital). This is a criterion-referenced educational inventory designed to characterize learning strengths and weaknesses as well as typical error patterns during the performance of academic tasks. Written expressive language, mathematics, and reading comprehension were evaluated using this process-oriented approach.

(a) The mathematics inventory consisted of paper-and-pencil computation items and word problems. This was designed to compare student's computational skills, conceptual understanding, and ability to apply appropriate mathematics operations.

(b) Written expression was assessed using a creative writing task. Three key words were presented and students were required to select one key word, a key sentence and then to generate a paragraph. Two outcome measures were used. The index of writing productivity was the total number of words produced in three minutes. The second outcome, language usage, was based on process ratings of thematic quality, which measured ideational fluency and quality of ideas.

(c) Reading comprehension was assessed with a series of silent reading passages. Students were required to retell the stories in their own words and to answer specific questions about these passages. Sequential organization, recall of main ideas, memory for detail, and ability to draw inferences, were evaluated.

Procedure

Each student was tested on a one-to-one basis in the school setting. The study took place during a three-month period. The order of task presentation was generally the same for all subjects. Each FAF measure preceded the educational outcome measure with which it was associated (e.g., the FAF Math task preceded the Math outcome). In general, these two sets of tasks were administered prior to the problem-solving tasks.

Statistical Analyses

Hierarchical regression analyses were applied to determine the contributions toward academic performance of the FAF automatization tasks and the problem-solving measures. In each of the four regression analyses, the nonspecific automatization measures were inserted first into the regression equations. Thereafter, the skill-specific automatization task was included. Finally, the two problem-solving tasks were added. The purpose of the analyses was to determine the extent to which the specific automatization measures and the problem-solving tasks contributed towards the prediction of educational performance over and above the generalized measures of fluent task performance. Although the simple correlations may have been higher for the skill-specific automatizations tasks, it was critical to remove any source of general variance using a partialing-out procedure in the regression equations.

Results

Table 1 presents the intercorrelations among the FAF automatization tasks and the measures dealing with the educational outcomes. The findings can be enumerated as follows:

Insert Table 1 about here

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1. The intercorrelations among the FAF measures ranged from .46 to .61.

2. The correlations between each FAF measure and the educational outcome specifically associated with the measure were .78 for math, .59 for writing-productivity and .41 for writing-language usage.

3. Correlations between FAF measures and educational outcomes not specifically associated with those measures (e.g., FAF Math with Reading) ranged from .36 to .67.

Table 2 presents the intercorrelations between the problem solving tasks and both the FAF and the outcome measures.

Insert Table 2 about here

Correlations between the problem-solving tasks and FAF measures ranged from .10 to .53, while the associations between problem-solving tasks and educational outcome ranged from .13 to .59.

Tables 3-5 present the results of multiple regression analyses in which the outcome measures served as dependent variables while the FAF measures and the tests of problem-solving served as predictors. Each of these analyses involved three steps:

1. The two FAF measures not specific to the outcome variables were entered on step 1. Thus, the R^2 value after this step represents the proportion of variance in the outcome measure which can be explained by measures of generalized automatization ability rather than outcome-specific skills.

2. The FAF measure specific to the outcome variable was entered on step 2. Therefore, the increment in R^2 from step 1 to step 2 represents the improved precision of the outcome when the specific FAF measure was added to the regression equation. This step already included measures of the generalized ability to automatize.

3. The problem-solving tasks were entered on step 3. The increment in R^2 from step 2 to step 3 represents the variance in outcome

which can be explained by problem-solving performance over and above that which has already been explained by the FAF Automatization measures.

The results of the regression analyses in the areas of Reading, Mathematics and Writing can be summarized as follows:

1. Reading

Insert Table 3 about here

The combined contribution of the FAF and problem-solving measures resulted in an overall R^2 of .53. Examination of these results indicated that the generalized FAF measure accounted for 47% of the variance, while the addition of the reading-specific FAF measure resulted in a statistically significant increment of 4% in R^2. The further addition of problem-solving measures failed to produce a significant increment in R^2.

2. Mathematics

Insert Table 4 about here

The combined contributions of all the predictor variables accounted for 66% of the variance in math performance. The stepwise analyses indicated that the generalized FAF measures produced an R^2 of .37 on the first step. The introduction of the math-specific FAF measure on step 2 resulted in a statistically significant increment of .25 in R^2. The further introduction of problem-solving measures into the equation produced an additional statistically significant increment of 4% in R^2.

3. Writing

Insert Table 5-A about here

With productivity (number of words produced) as the dependent variable, the combination of predictors produced an overall R^2 of .28. Stepwise analyses revealed that the generalized FAF measure accounted for 25% of the variance on Step 1 and that the addition of the writing-specific FAF measure resulted in a statistically significant R^2 increment of .03 on step 2. The further addition into the equation of problem-solving resulted in no significant changes in R^2.

Using written language ratings as the dependent variable, the combination of predictors again accounted for 28% of the outcome variance.

Insert Table 5-B about here

Here the generalized FAF measure produced an R^2 of .19 on step 1 and introduction of the specific FAF variable produced a statistically significant 4% increment in R^2 on step 2. The further addition of problem-solving measures resulted in an additional statistically significant R^2 increment of 5%. The ability to shift strategies emerged as the dominant problem-solving variable.

Discussion and Conclusion

The findings of the study suggest a number of major themes. First, prediction of the four educational outcomes differed with respect to the relative contributions of the FAF automatization measures to the problemsolving tasks. More outcome variance was explained for reading comprehension and mathematics than for written language. These results indicate the importance of exercising caution when research findings are extrapolated from one educational area to another. In particular, automatization research should probably consist of direct

investigations of specific educational outcomes so that generalizations are not drawn from the area of reading alone.

A second major theme was that outcome-specific FAF measure was much more dominant for mathematics than for the other educational areas. Reading comprehension and written language performance were explained primarily by generalized automatization processes, with the outcome-specific FAF measures explaining relatively small, although statistically significant proportions of variance. These findings suggest that specific mathematics deficits could be remediated using instruction and rote drill in operations such as addition, subtraction, multiplication and division. In contrast, rote memory and review of basic vocabulary and alphabetic letters may be less important for improving reading comprehension and written language.

The third major theme concerns the contributions of the problem-solving measures towards mathematics and written language usage. The present findings suggest that performance in these academic skills becomes proficient when the basic mathematics and writing processes are automatic, thus freeing processing space for the more abstract and cognitively demanding components of these tasks. In other words, output in mathematics and written language seem to depend on well-automatized generalized and specific educational skills, in combination with meta-cognitive strategies such as the ability to organize information, to detect themes and to plan. Research is currently underway to examine further the role of problem-solving strategies in reading comprehension and written productivity.

Finally, this study supports the inclusion in diagnostic inventories of skill-specific automatization measures as well as problem-

solving tasks. In this study each of these played a unique and significant role in educational performance. It is apparent, therefore, that the incorporation of these tasks could result in more precise assessment and more appropriate intervention. Training procedures derived from such multifaceted diagnostic methods may improve the incidence of long-term remedial success and reduce the proportion of children who continue to fail despite remediation.

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Table 1

Correlations among the FAF Automatization Tasks and the Educational Outcome Measures (n=127)

		FAF Math	FAF Writing	FAF Reading
FAF Tasks	FAF-Math	1.00		
	FAF-Writing	.52	1.00	
	FAF Reading	.61	.46	1.00
Outcome Measures	Math Application	.78	.47	.55
	Writing-Productivity	.47	.42	.41
	Writing-Language Usage	.42	.41	.36
	Reading Comprehension	.67	.47	.59

Note: Math Application=Grade-equivalent score based on computation and word problems.

Writing-Productivity=Volume of written production (number of words produced in three minutes).

Writing-Language Usage=Process ratings of paragraph writing based on thematic continuity, ideational fluency, language usage, and quality of ideas.

Reading Comprehension=Oral reformulation of a reading passage which has been read silently.

Table 2

Correlations between the Problem-Solving Tasks and the Educational FAF Automatization and Outcome Measures (n=127)

	Series Completion	Categorization	Matrices	Category Shift	Seq. Reasoning	Classi-fication	Series Ex.	Shift Ex.
FAF Math	.26	.28	.33	.26	.49*	.52	.40	.53*
FAF Writing	.05	.09	.19	.17	.38	.32	.10	.33
FAF Reading	.36	.22	.23	.31*	.42*	.43	.36	.44*
Math-application	.35	.27	.40	.31*	.51*	.55	.41	.59*
Writing-Productivity	.28	.26	.17	.17	.27	.40*	.27	.28
Writing-Language Usage	.19	.14	.25	.28	.38	.22	.13	.42*
Reading Comprehension	.36	.18	.39	.28	.43*	.51	.37	.47*

Note: See Table 1 for key to educational measures.

Table 3

Reading Comprehension: Incremental Contributions of the FAF Automatization Tasks and the Problem-Solving Measures (n=127)

Step	Predictor Variable	R	R^2	R^2_{change}	F_{change}	F_{total}
1	FAF Math	.67	.45	.45	103.24***	103.24***
	FAF Writing	.69	.47	.02	5.11*	55.87***
2	FAF Reading	.72	.51	.04	10.18**	43.40***
3	Category Shift	.72	.52	.009	2.25	33.44***
	Series	.73	.53	.005	1.34	27.09***

Note: 1. Hierarchical regression analyses applied.
2. Order of entry of independent variables predetermined according to hypothesized relationships.

Table 4

Mathematics performance: Incremental Contributions of the FAF Automatization Tasks and the Problem Solving Measures (n=127)

Step	Predictor Variable	R	R^2	R^2_{change}	F_{change}	F_{total}
1	FAF Reading	.55	.31	.31	55.01***	55.01***
	FAF Writing	.60	.37	.06	11.63***	35.66***
2	FAF Math	.79	.62	.25	81.56***	66.41***
3	Category Shift	.81	.65	.04	12.22***	57.40***
	Series	.82	.66	.01	1.90	46.64***

Note: Hierarchical regression analyses applied

Table 5-A

Writing Productivity: Additive Contributions of the FAF Automatization and the Problem-Solving Measures (n=127)

Step	Predictor Variable	R	R^2	R^2_{change}	F_{change}	F_{total}
1	FAF Math	.47	.22	.22	35.57***	35.57***
	FAF Reading	.50	.24	.02	3.77	20.07***
2	FAF Writing	.53	.28	.03	5.23*	15.58**
3	Series	.55	.28	.01	1.50	12.11***
	Category Shift	.57	.28	.001	0.06	9.62**

Note: Hierarchical regression analyses applied. Writing Productivity measured in terms of the toal number of words produced when writing a paragraph using a keyword.

Table 5-B

Writing-Language Usage: Additive Contributions of the FAF Automatization and the Problem-Solving Measures (n=127)

Step	Predictor Variable	R	R^2	R^2_{change}	F_{change}	F_{total}
1	FAF Math	.42	.17	.17	26.29***	26.29***
	FAF Reading	.44	.19	.02	2.79	14.73***
2	FAF Writing	.48	.23	.04	6.48*	12.41***
3	Category Shift	.53	.28	.04	7.35*	11.63***
	Series	.53	.28	.004	0.72	9.43**

Note: Language Usage was measured using process-based ratings of grammatical complexity, thematic continuity, idea density and abstract/concrete thinking.

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